

Safety Manual

E2 Series Transducer

Document: E2_Series_Transducer_SM-001
Rev. B

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1 Introduction

This Safety Manual provides information necessary to design, install, verify and maintain a Safety Instrumented Function (SIF) utilizing the E2 Series Transducer. This manual provides the necessary requirements for meeting the IEC 61508 or IEC 61511 functional safety standards.

1.1 Terms

Safety	Freedom from unacceptable risk of harm.
Functional Safety	The ability of a system to carry out the actions necessary to achieve or to maintain a defined safe state for the equipment / machinery / plant / apparatus under control of the system.
Basic Safety	The equipment must be designed and manufactured such that it protects against risk of damage to persons by electrical shock and other hazards and against resulting fire and explosion. The protection must be effective under all conditions of the nominal operation and under single fault condition.
Safety Assessment	The investigation to arrive at a judgment - based on evidence - of the safety achieved by safety-related systems.
Span	The difference between full scale (maximum measurable pressure) and offset (minimum measurable pressure).
Fail-Safe State	State where solenoid valve is de-energized and spring is extended.
Fail Safe	Failure that causes the valve to go to the defined fail-safe state without a demand from the process.
Fail Dangerous	Failure that does not respond to a demand from the process (i.e., being unable to go to the defined fail-safe state).
Fail Dangerous Undetected	Failure that is dangerous and that is not being diagnosed by automatic stroke testing.
Fail Dangerous Detected	Failure that is dangerous but is detected by automatic stroke testing.
Fail Annunciation Undetected	Failure that does not cause a false trip or prevent the safety function but does cause loss of an automatic diagnostic and is not detected by another diagnostic.
Fail Annunciation Detected	Failure that does not cause a false trip or prevent the safety function but does cause loss of an automatic diagnostic or false diagnostic indication.
Fail No Effect	Failure of a component that is part of the safety function but that has no effect on the safety function.
Low demand mode	Mode, where the frequency of demands for operation made on a safety-related system is no greater than twice the proof

test frequency.

Abbreviations

ANSI	American National Standards Institute
CT	Connecticut
DU	Dangerous Undetected
FMEDA	Failure Modes, Effects and Diagnostic Analysis
HFT	Hardware Fault Tolerance
IEC	International Electrotechnical Commission
ISA	International Society of Automation
ISBN	International Standard Book Number
MOC	Management of Change. These are specific procedures often done when performing any work activities in compliance with government regulatory authorities.
PFDavg	Average Probability of Failure on Demand
SFF	Safe Failure Fraction, the fraction of the overall failure rate of a device that results in either a safe fault or a diagnosed unsafe fault.
SIF	Safety Instrumented Function, a set of equipment intended to reduce the risk due to a specific hazard (a safety loop).
SIL	Safety Integrity Level, discrete level (one out of a possible four) for specifying the safety integrity requirements of the safety functions to be allocated to the E/E/PE safety-related systems where Safety Integrity Level 4 has the highest level of safety integrity and Safety Integrity Level 1 has the lowest.
SIS	Safety Instrumented System – Implementation of one or more Safety Instrumented Functions. A SIS is composed of any combination of sensor(s), logic solver(s), and final element(s).

1.2 Product Support

Product support can be obtained from:

Ashcroft Inc., 250 East Main Street, Stratford, CT 06614

www.ashcroft.com

203-385-0635

1.3 Related Literature

Hardware Documents:

- E2G Pressure Transducer Installation Manual
- E2X Explosion Proof Pressure Transducer Installation Manual

- E2S Intrinsically Safe and Non-incendive Pressure Transducer Installation Manual
- E2F Explosion/Flame Proof Pressure Transducer Installation Manual
- Datasheet – E2G Pressure Transducer
- Datasheet – E2X-E2F Explosion-Proof Pressure Transducer
- Datasheet – E2S Intrinsically Safe Pressure Transducer

Guidelines/References:

- Safety Integrity Level Selection – Systematic Methods Including Layer of Protection Analysis, ISBN 1-55617-777-1, ISA
- Control System Safety Evaluation and Reliability, 2nd Edition, ISBN 1-55617-638-8, ISA
- Safety Instrumented Systems Verification, Practical Probabilistic Calculations, ISBN 1-55617-909-9, ISA

1.4 Reference Standards

Functional Safety

- IEC 61508: 2010 Functional safety of electrical/electronic/ programmable electronic safety-related systems
- ANSI/ISA 84.00.01-2004 (IEC 61511 Mod.) Functional Safety – Safety Instrumented Systems for the Process Industry Sector

2 Device Description

The models E2G, E2X, E2S and E2F (E2 series) are pressure transducers/transmitters intended to measure process fluids (liquid or gases), providing a single variable analog output (voltage or current) proportional to the measured pressure.

These models can be identified by the first 3 characters of the model printed on the label or laser marked on the product.

Each transducer is assigned a unique S/N which is either printed or laser marked on the product. Not all output configurations of E2 series transducer meet SIL criteria. See section 3.5.2 and table 1. The S/Ns that meet all the following criteria are covered by the certification.

1. First three characters are ESU.
2. Subsequent 4 digits, which is a date code in YYMM format, is 2310 or greater. (e.g. 2311, 2410, etc.)

3 Designing a SIF Using a Customer Product

3.1 Safety Function

The safety function of the E2 series pressure transducer is to convert a pressure to an analog electrical output (e.g., 4-20mA current loop, 1-5 volts, etc.) within the safety accuracy of +/- 3% of span.

The E2 series pressure transducer has internal diagnostics functions that are annunciated either with high or low fault signal levels.

The E2 series transducer is intended to be a sensor or be part of final element subsystem of a Safety Instrumented Function (SIF), as defined per IEC 61508 and the achieved SIL level of the designed function must be verified by the designer.

3.2 Environmental limits

The designer of a SIF must check that the product is rated for use within the expected environmental limits. Refer to the E2 series transducer datasheet available at www.Ashcroft.com for environmental limits.

3.3 Application limits

The materials of construction of the E2 series transducer are specified in the datasheet. It is especially important that the designer checks for material compatibility considering on-site chemical contaminants and air supply conditions. If the E2 series Transducer is used outside of the application limits or with incompatible materials, or is modified without the authorization of the manufacturer, the reliability data provided becomes invalid.

3.4 Design Verification

A detailed Failure Mode, Effects, and Diagnostics Analysis (FMEDA) report is available from Ashcroft Inc. This report details all failure rates and failure modes as well as the expected lifetime.

The achieved Safety Integrity Level (SIL) of an entire Safety Instrumented Function (SIF) design must be verified by the designer via a calculation of PFD_{avg} considering architecture, proof test interval, proof test coverage, any automatic diagnostics, average repair time and the specific failure rates of all products included in the SIF. Each subsystem must be checked to assure compliance with minimum hardware fault tolerance (HFT) requirements. The exida exSILentia® tool is recommended for this purpose as it contains accurate models for the E2 series pressure transducer and its failure rates.

When using an E2 series transducer in a redundant configuration, a common cause factor of at least 5% should be included in safety integrity calculations.

The failure rate data listed in the FMEDA report is only valid for the useful life time of the E2 series transducer. The failure rates will increase sometime after this time period. Reliability calculations based on the data listed in the FMEDA report for mission times beyond the lifetime may yield results that are too optimistic, i.e., the calculated Safety Integrity Level will not be achieved.

3.5 SIL Capability

3.5.1 Systematic Integrity

The E2 series transducer has met manufacturer design process requirements of Safety Integrity Level (SIL) 3. These are intended to achieve sufficient integrity against systematic errors of design by the manufacturer. A Safety Instrumented Function (SIF) designed with this product must not be used at a SIL level higher than the statement without “prior use” justification by end user or diverse technology redundancy in the design.

3.5.2 Random Integrity

The E2 series transducer is a Type B Device. Per the E2 FMEDA report, the failure rate data used meets the exida criteria for Route 2_H which is more stringent than IEC 61508-2. Therefore, the E2 series transducer, excluding some output versions, meets the hardware architectural constraints for up to SIL 2 @ HFT=0 (or SIL 3 @ HFT=1) in low demand mode when the logic solver can detect out of range outputs.

The E2 series transducer is available with various output types per datasheet, and only some output types meet the SIL criteria. Failure rates differ based on output types and they are grouped as summarized in the table below. Refer to the group name that FMEDA report references to obtain corresponding failure rates from the report.

Table 1: Output types		
Output versions provided in FMEDA report table 2	Corresponding E2 series output types	Available approaches to determine the architectural constraints per IEC 61508-2
4-20mA	4-20mA, 20-4mA	Both Route 1 _H & 2 _H
1-5V	1-5 Vdc, 1-6 Vdc, 0.5-4.5 Vdc, 1-11 Vdc	
0-10V	0-5 Vdc, 0-10 Vdc, 0.1-5 Vdc, 0.1-10 Vdc	Does not meet SIL criteria

When the final element assembly consists of many components (this transducer, actuator, solenoid, quick exhaust valve, etc.) the SIL must be verified for the entire assembly using failure rates from all components. This analysis must account for any hardware fault tolerance and architecture constraints.

3.5.3 Safety Parameters

For detailed failure rate information refer to the FMEDA Report for the E2 series transducer.

The useful life of an E2 series transducer is discussed in the Failure Modes, Effects and Diagnostic Analysis Report and also provided in section 5.3 of this manual.

3.6 Connection of the E2 series transducer to the SIS Logic-solver

The E2 series transducer is connected to the safety rated logic solver which is actively performing the logic of the safety function as well as automatic diagnostics designed to diagnose potentially dangerous failures within the SIF.

The E2 series transducer's worst case internal diagnostic test interval is 30 seconds and detection of a fault results in E2's output driven high or low beyond normal output range (See table 2). For the failure rates provided for 4-20mA or 1-5V output versions of E2 series transducer to be effective, the application program in the logic solver must be constructed in such a way that High fault and Low fault signals are detected regardless of the effect, safe or dangerous, on the safety function.

Persistent failures will annunciate continuously until the transducer is reset. Transient failures will annunciate while the fault condition is present and will cease annunciating when the fault condition clears, with a minimum of 2 milliseconds. Contact Ashcroft for the list of detectable failures.

If the output at low fault signal or high fault signal specified in table 2, the transducer indicates a fault condition and is no longer operational.

Table 2: Fault signal output levels		
E2 series Output types	Low fault signal	High fault signal
4-20 mA	<3.60 mA	>21.00 mA
20-4 mA	>21.00 mA	<3.60 mA

1-5 Vdc	<0.900 Vdc	>5.250 Vdc
1-6 Vdc	<0.875 Vdc	>6.313 Vdc
0.5-4.5 Vdc	<0.400 Vdc	>4.750 Vdc
1-11 Vdc	<0.750Vdc	>11.500 Vdc

3.7 General Requirements

The E2 series transducer's response time shall be less than process safety time. An E2 series transducer will indicate applied pressure in less than 1 second after a step change of pressure.

All SIS components including the E2 series transducer must be operational before process start-up.

User shall verify that the E2 series transducer is suitable for use in safety applications by confirming the E2 series transducer's nameplate is properly marked.

Personnel performing maintenance and testing on an E2 series transducer shall be competent to do so.

Results from the proof tests shall be recorded and reviewed periodically.

4 Installation and Commissioning

4.1 Installation

The E2 series transducer must be installed per standard practices outlined in the Installation Manual.

The environment must be checked to verify that environmental conditions do not exceed the ratings.

The E2 series transducer must be accessible for physical inspection.

4.2 Physical Location and Placement

The E2 series transducer shall be accessible with sufficient room for pressure and electrical connections and shall allow manual proof testing.

The E2 series transducer shall be mounted in a low vibration environment. If excessive vibration can be expected special precautions shall be taken to ensure the integrity of connections or the vibration should be reduced using appropriate damping mounts.

4.3 Pressure Connections

It is the responsibility of the designer of the SIF to ensure that the pressure connections used when installing an E2 series transducer are rated for the operating pressure of the system, and do not restrict the pressure to the transducer.

5 Operations and Maintenance

5.1 Proof test without automatic testing

The objective of proof testing is to detect failures within the E2 series transducer that are not detected by any automatic diagnostics of the system. The primary concern is undetected failures that prevent the safety instrumented function from performing its intended function.

The frequency of proof testing, or the proof test interval, is to be determined in reliability calculations for the safety instrumented functions for which an E2 series transducer is applied. The proof tests must be performed more frequently than or as frequently as specified in the calculation to maintain the required safety integrity of the safety instrumented function.

The following proof test is recommended. The results of the proof test should be recorded and any failures that are detected and that compromise functional safety should be reported to Ashcroft.

Step	Action
1	Bypass the safety function and take appropriate action to avoid a false trip.
2	Power cycle the E2 series transducer ¹
3	Verify calibration of the E2 series transducer by confirming the output to be within the safety accuracy.
4	Inspect the E2 series transducer for any visible damage, process blockage or contamination.
5	Record any failures in your company's SIF inspection database, and replace faulty devices (See 5.2 for details)
6	Remove the bypass and otherwise restore normal operation.

Table1: Recommended Proof Test

This test will detect >90% of possible DU failures in the E2 series transducer.

The person(s) performing the proof test of an E2 series transducer should be trained in SIS operations, including bypass procedures, transducer maintenance and company Management of Change procedures. No special tools are required.

NOTE: The E2 series transducer is available with Offset and Span adjustments feature. This feature is not a part of the proof test recommended. However, this feature may be used to re-calibrate the output of an E2 series transducer. See the E2 series transducer installation manual for the procedure. If an E2 series transducer is re-calibrated as a part of the proof test, step 2 above must be repeated after the adjustment to re-verify the calibration. The person(s) performing the Offset and Span adjustments should be trained in SIS operations, including bypass procedures, transducer maintenance and company Management of Change procedures. Ashcroft calibration magnet is required to access this feature.

¹ This step ensures that various startup tests run on E2 series Transducer.

5.2 Repair and replacement

The E2 series transducer is not repairable. The person(s) performing the replacement of an E2 series transducer should be trained in SIS operations, including bypass procedures, transducer maintenance and company Management of Change procedures.

5.3 Useful Life

The useful life of the E2 series transducer is 50 years. 50 years was used in FMEDA report.

5.4 Manufacture Notification

Any failures that are detected and that compromise functional safety should be reported to Ashcroft. Please contact Ashcroft customer service.

6 Start-Up Checklist

The following checklist may be used as a guide to employ the E2 series pressure transducer in a safety critical SIF compliant to IEC 61508.

#	Activity	Result	Verified	
			By	Date
	Design			
	Target Safety Integrity Level and PFDavg determined			
	Correct valve mode and threshold value chosen (threshold output for valve to open/close)			
	Design decision documented			
	Pneumatic compatibility and suitability verified			
	SIS logic solver requirements for the valve tests defined and documented			
	Routing of pneumatic connections determined			
	SIS logic solver requirements for partial stroke tests defined and documented			
	Design formally reviewed and suitability formally assessed			
	Implementation			
	Physical location appropriate			
	Pneumatic connections appropriate and according to applicable codes			
	SIS logic solver valve actuation test implemented			
	Maintenance instructions for proof test released			
	Verification and test plan released			

#	Activity	Result	Verified	
			By	Date
	Implementation formally reviewed and suitability formally assessed			
	Verification and Testing			
	Electrical connections verified and tested			
	Pneumatic connection verified and tested			
	SIS logic solver valve actuation test verified			
	Safety loop function verified			
	Safety loop timing measured			
	Bypass function tested			
	Verification and test results formally reviewed and suitability formally assessed			
	Maintenance			
	Pipe blockage / partial blockage tested			
	Safety loop function tested			

7 Status of the Document

7.1 Releases

Version: <V0>

Revision:

Version History: V0, A: New release

V0, B: Updated proof test procedure (Sect. 5.1) and added minimum fault annunciation time (Sect. 3.6)

Authors: David Dlugos, Tomi Kuramoto

Release status: Released

7.2 Future Enhancements

At request of project.

7.3 Release Signatures



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